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Effects of cross-fostering within 24 h after birth on pre-weaning behaviour, growth performance and survival rate of biological and adopted piglets

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ABSTRACT

Cross-fostering is the transference of piglets to equalise litter size according to the birth weight. In many commercial farms piglets are usually grouped in litters with 100% adopted piglets. The aim of the experiment was to assess the behaviour of piglets during the suckling period as well as to assess their performance and mortality rate up to weaning in litters with different composition in terms of adopted and biological piglets. Three treatments were studied: 100B (100% biological piglets, $n=13$), 50B50A (50% biological piglets and 50% adopted piglets, $n=13$) and 100A (100% adopted piglets, $n=13$). All litters were standardised to eleven piglets on average within 20.1 ± 0.4 h (14.3–24.7 h) of birth. The behaviour of piglets was recorded during four consecutive sucklings for four days (days 1, 2, 4 and 6 after farrowing, considering day 1 as the cross-fostering day). The observations were performed at two time periods: TP1 (from release of piglets out of creep box until milk letdown) and TP2 (from the end of milk letdown up to 15 min later). Piglets were weighed at days 1, 4, 7, 10, 13 and 16. There were no differences ($P > 0.05$) among the treatments in the following behavioural variables: percentage of missed nursing episodes; number of fights for teats and percentage of piglets involved in fights at TP1; percentage of piglets vocalising at TP1 and at TP2; number of fights per piglet elsewhere in the cage and percentage of piglets involved in these fights; number of instances of playful behaviour per piglet and percentage of piglets involved in it. At TP2 of day 1, 100B piglets displayed a lower number ($P < 0.05$) of fights for teat (0.9 vs. 1.6 vs. 1.4 for 100B, 100A and 50B50A, respectively) and tended to have a lower percentage ($P < 0.07$) of piglets involved in these fights than 100A (49.6%, 67.2% and 64.9% for 100B, 100A and 50B50A, respectively). Nutritive nursing episodes (overall medians of 4.0, 3.0, 4.0 and 4.0 for days 1, 2, 4 and 6, respectively), survival rate (overall 97.2%) and average weight of piglets (1983 g, 2650 g, 3411 g, 4207 g and 5047 g for days 4, 7, 10, 13 and 16, respectively) were similar ($P > 0.05$) among treatments. Cross-fostering performed on average at 20 h after birth has no adverse effects on survival and growth performance of adopted piglets.

1. Introduction

The increased sow prolificacy, observed with advances in genetic improvement, is associated with a large variability in birth weight and a higher pre-weaning piglet mortality rate (Alonso-Spilsbury et al., 2007; Milligan et al., 2001; Quiniou

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et al., 2002). It is important to adopt management practices such as cross-fostering to reduce the detrimental effect of low birth weight on pre-weaning survival.

Cross-fostering is the transference of piglets to equalise litter size according to birth weight, aiming at a reduction in pre-weaning mortality (Robert and Martineau, 2001; Straw et al., 1998). The higher immunoglobulin absorption takes place until 12 h after the farrowing and a loss in gut permeability occurs 24 and 36 h afterwards (Lecce et al., 1961; Lanza et al., 1995). Cross-fostering should be performed between 12 and 24 h after farrowing, before teat order has been established, so piglets could absorb the maximum of colostrum immunoglobulins and lymphocytes from their genetic dams (Bandrick et al., 2008, 2011; Pieters et al., 2008; Robert and Martineau, 2001; Straw et al., 1998).

Continuous cross-fostering throughout lactation is intended to decrease body weight variation within litters (Rzasa et al., 2002), but it can be stressful for both piglets and sows. Moreover, it can have detrimental effects on piglets' behaviour without improving body weight at weaning (Horrell and Bennett, 1981; Milligan et al., 2001; Neal and Irvin, 1991; Price et al., 1994; Robert and Martineau, 2001). Also, infection hazard and pre-weaning mortality rate may increase as piglets are exposed to an environment with pathogenic agents against which they may not have any adequate protection (Wills et al., 1997).

In commercial farms, piglets are cross-fostered for many reasons: (1) too many piglets born alive and the surplus ones are fostered to create new litter groups; (2) small and weak piglets are grouped in eight or ten together onto a sow with good teat access to increase their survivability; (3) savaging—if a gilt or sow does not respond to sedation it is necessary to foster the whole litter; (4) death of a sow at farrowing—it is necessary to foster the whole litter. The aim of the experiment was to assess the behaviour of good birth weight (1065–1940 g) and vigour score piglets during the suckling period as well as to assess their performance and survival rate up to weaning in litters with different composition in terms of adopted and biological piglets.

2. Materials and methods

All experimental procedures described in this experiment were conducted under experimental licence (Project number 18327) from the Institutional Animal Care and Use Committee (COMPESQ-FAVET-UFRGS).

2.1. Animals and treatments

This experiment was carried out on a commercial swine unit of 2900 sows in south of Brazil, Santa Catarina state and involved 39 sows of parity five (Agroceres PIC® genetics, C23) with at least 12 functional teats.

The sows were housed in cages during the gestation period and approximately one week before estimated farrowing date, they were moved into the farrowing house and individually housed in pens until weaning. The farrowing house consisted of 32 pens (2.2 m × 2.4 m) per room and curtains at the lateral walls to manage the temperature of the room. The observations took place in seven rooms during the whole experiment—one room per week. The farrowing pen had a crate in its centre, with slatted plastic floor and a creep box in front of the crate. The creep box contained heat lamps and an opening to permit the piglets' entrance and exit. Piglets could access both spaces situated at sides of the crate (inaccessible to the sow). Temperature control was based on the curtain management. The average temperature of farrowing houses was 23.4 °C (26.3 and 21.6 °C for average maximum and minimum temperature, respectively) whereas the average temperature of the creep box was 27.6 °C (30.2 and 25.5 °C for average maximum and minimum temperature, respectively).

The farrowings were induced by prostaglandin administration on days 113–114 of gestation and they were attended. Farm management was performed equally for the three treatments. Sows received specific amounts of feed in the following quantities: 3 kg/d of pre-lactation diet (3153 kcal/kg ME, 17% CP and 0.9% lysine) until the predicted date of farrowing. They were fed twice a day. On the predicted date of farrowing 1.0 kg of pre-lactation diet was provided per sow. Sows received 1.0 kg of lactation diet (3330 kcal/kg ME, 19.4% CP and 1.1% lysine) on the first day after farrowing, and then the feed supply was increased to 4 kg on the third day. Afterward, sows were fed nearly ad libitum with three equal meals provided at 08:00, 14:00 and 20:00 h. Creep feed was offered to piglets from six days after birth until weaning (3450 kcal/kg ME, 20.8% CP and 1.45% lysine). Both sows and piglets had ad libitum access to drinking water.

The piglets were cross-fostered 20.1 ± 0.4 h (14.3–24.7 h) after farrowing. Litter size was adjusted to 11 piglets per sow, with a birth vigour score 1. Birth vigour was subjectively scored in a scale from 1 to 4, with 1 being strongest (i.e., score 1: freedom to move around the pen, to find the creep box and to suckle effectively) and 4 being the weakest piglets (Neal and Irvin, 1991). At cross-fostering piglets were individually weighed (average: 1454.9 ± 11.9 g; range of 1065–1940 g), ear-tagged and allocated into three treatments (13 litters per treatment): 100B (100% biological piglets), 50B50A (50% biological piglets and 50% adopted piglets) and 100A (100% adopted piglets). A uniform distribution of piglets into the treatments was performed according to birth weight and gender. In 50B50A treatment, six and five female piglets were alternately distributed so that by the end there was almost the same number of biological ($n=71$) and adopted ($n=72$) female piglets. Adopted piglets were all issued from fifth parity non-experimental sows, one or two donors being used for each fostering mother in 50B50A treatment and two or three donors for each fostering mother in 100A treatment. In 100B treatment, the surplus piglets were removed, when necessary, and fostered to non-experimental sows.

2.2. Measurements

2.2.1. Behavioural observations

In order to evaluate the behaviour of piglets during nursing, four consecutive nursings were evaluated by direct visual observation over four days (days 1, 2, 4 and 6 after farrowing, considering day 1 as the cross-fostering day). During six weeks, six sows (two sows per treatment) and their litters were evaluated per week (36 sows) and on the seventh week, the last three sows (one sow per treatment) and their litters were evaluated (total of 39 sows). All evaluations were performed by a single person who has undergone previous training and assessed a litter at a time. Piglets were marked with sequential numbers on their back with a commercial livestock-marking pen for better identification during the observation period. These markings were renewed during the evaluation periods. This number remained the same for each piglet in every assessment and the identity of adopted and biological was made clear by different ear-tag colour. At the beginning of each assessment, piglets were released from the creep box; at the end of evaluation, the piglets were held in the creep box for 50 min until next assessment, to make sure they would not suckle between successive evaluations.

The observation period was divided into two time periods: time period 1 (TP1—from release of piglets out of the creep box until milk letdown) and time period 2 (TP2—from the end of milk letdown up to 15 min later). The pre-ejection milk massaging phase and milk letdown, whose duration is respectively 1–3 min (Algers and Jensen, 1985; Algers, 1993; Algers and Uvnäs-Moberg, 2007; Fraser, 1980), and 10–20 s (Algers and Uvnäs-Moberg, 2007; Ellendorff et al., 1982; Fraser, 1980) were covered by TP1. Post letdown milk massaging phase was extended to 15 min afterward (Jensen et al., 1998), being covered by TP2.

The following variables were recorded during TP1: number of fights for teats, percentage of piglets involved in fights for teats, percentage of piglets vocalising, percentage of missed nursing episodes and number of nutritive sow nursings. The variables recorded during TP2 were the following: number of fights for teats, number of fights elsewhere in the cage, percentage of piglets involved in these fights, percentage of piglets vocalising, number of instances of playful behaviour and percentage of piglets involved in playful behaviour. Even in cases of non-nutritive nursings (without milk letdown), piglets were evaluated (vocalising, playful behaviour and fights elsewhere in the cage) for 15 min at TP2, and after this period piglets were kept in the creep box. The definition of the specific behaviour evaluated at TP1 and TP2 is described in Table 1.

2.2.2. *Growth performance*

Piglets were individually weighed at days 1 (cross-fostering day), 4, 7, 10, 13 and 16 after farrowing. Piglets were weaned at day 16 after farrowing.

2.3. *Statistical analysis*

For all statistical analyses the Statistical Analysis System software, version 9.1.3, was used (SAS Institute Inc., 2005). All variables were analysed using litters as experimental units. The analyses were carried out taking into account the original treatments (100A, 100B and 50A50B) but other comparisons were also performed: 50A × 50B piglets, and biological (50B, 100B) × adopted (50A, 100A) piglets. Data are presented as means ± standard error of mean unless stated otherwise.

Number of fights for teat, number of fights elsewhere in the cage, and number of instances of playful behaviour were expressed as the observed number of these events divided by the number of piglets in each litter. Vocalisation and also the involvement in fights or playful behaviour were expressed as percentages over the total of piglets per litter showing this particular behaviour.

All data were tested for normality by the Shapiro-Wilk test. Because they showed a non-normal distribution, the number of fights per piglet was transformed by logarithm $(X+1)$ whereas the percentage of missed nursing episodes, and the percentage of piglets involved in fights for teats were submitted to arcsine square root transformation before being analysed by the GLM procedure. Values for these variables are, however, presented as means ± standard errors of non-transformed data.

Even when submitted to the recommended transformations (Steel and Torrie, 1980), some variables failed to follow a normal distribution: number of nutritive nursing episodes, percentage of vocalising piglets, number of playful behaviour instances and percentage of piglets involved in playful behaviour, number of fights and percentage of piglets involved in fights elsewhere in the cage, and survival rate. These variables were thus submitted to non parametric analysis using the NPAR1WAY procedure and values are presented as medians. In these cases, treatments were compared by the Kruskal–Wallis test.

Piglet weight was analysed as repeated measures by the MIXED procedure, with fixed effect of litter type, time period of evaluation and interaction between these two factors. Birth weight was maintained as a covariate in the model of analysis. LSmeans were compared by the Tukey test and differences were considered as significant at $P<0.05$ or as trends for P-values between 0.05 and 0.10.

3. Results

Nutritive nursing episodes were similar ($P>0.05$) among the treatments (overall medians of 4.0, 3.0, 4.0 and 4.0 for days 1, 2, 4 and 6, respectively) during the four consecutive evaluated nursing days. Only two sows (5.1%) were aggressive with their piglets (sow snapping—making a sudden, rapid biting movement toward the piglet) and only in the first nursing episode after cross-fostering, one sow from the 100A treatment (four piglets involved) and another from 50B50A (two biological piglets and one adopted involved).

Percentage of missed nursing episodes was not different ($P>0.05$) among treatments (overall means of 26.8 ± 2.06%, 16.9 ± 1.99%, 6.0 ± 1.17% and 3.6 ± 0.97% at days 1, 2, 4 and 6, respectively). However, when piglets of 50B50A treatment were analysed separately, adopted piglets (50A) lost more nursing episodes ($P<0.05$) at day 1 (34.5 ± 3.7% vs. 24.8 ± 2.9%) than the biological ones (50B).

There were no differences ($P>0.05$) in the number of fights for teats (0.54 ± 0.07, 0.34 ± 0.03, 0.13 ± 0.02 and 0.10 ± 0.02 fights per piglet at days 1, 2, 4 and 6, respectively) and in percentage of piglets involved in fights for teats (46.2 ± 2.71%, 34.9 ± 2.08%, 16.0 ± 2.04%

Table 1
Definition of behaviour observed on pre and post milk letdown time periods.

Category	Definition
Milk letdown	The moment when piglets changed from slow jaw movements to faster ones and continued intensive suckling for about 15 s
Nutritive nursing	Piglets suckling intensively for about 15 s without interspersing teat massage or moving around. The beginning of nursing was considered when more than half of the piglets were actively manipulating the udder. The finishing of nursing was established when more than half of the litter had left the udder or was inactive next to it
Fight	An aggressive behaviour, an attack (including head knocks and biting), a displacement event with physical contact or any shoulder knock at teat or anywhere on the cage. The beginning of a fight was considered when one piglet attacked another one for at least 3 s. The end of a fight was established when piglets remained separated for at least 3 s
Playful behaviour	When two piglets interacted sociably, without aggression; a new playful episode was considered when repeated after 30 s

Adapted from Fraser (1980), Whatson and Bertram (1980), Petersen and Vestergaard (1989), Wiegand et al. (1994), Erhard et al. (1997), Wattanakul et al. (1998), Milligan et al. (2001) and Robert and Martineau (2001).

Table 2
Number of fights for teats and percentage of piglets involved in these fights during 15 min after milk ejection (time period—TP2) in four consecutive nursing episodes at day 1 (D1), day 2 (D2), day 4 (D4) and day 6 (D6).

Variables	100A[1]	100B[1]	50B50A[1]
Number of fights per piglet for teats[2]—D1	1.6 ± 0.2^{a}	0.9 ± 0.2^{b}	1.4 ± 0.1^{a}
Number of fights per piglet for teats[2]—D2	$0.7 \pm 0.2^{e,f}$	0.5 ± 0.06^{f}	0.9 ± 0.2^{e}
Number of fights per piglet for teats[2]—D4	0.4 ± 0.1	0.2 ± 0.5	0.3 ± 0.07
Number of fights per piglet for teats[2]—D6	0.2 ± 0.06	0.2 ± 0.05	0.3 ± 0.08
Piglets involved in fights for teats[2] (%)—D1	67.2 ± 4.0^{c}	49.6 ± 7.6^{d}	$64.9 \pm 4.0^{c,d}$
Piglets involved in fights for teats[2] (%)—D2	37.8 ± 5.1	32.5 ± 3.3	40.6 ± 2.9
Piglets involved in fights for teats[2] (%)—D4	22.0 ± 4.4	25.0 ± 3.1	26.1 ± 4.6
Piglets involved in fights for teats[2] (%)—D6	19.0 ± 5.3	22.3 ± 4.8	25.4 ± 4.8

Values correspond to LSmeans ± SEM of non-transformed data. [a,b] Differ ($P<0.05$); [c,d] tend to differ ($P<0.07$); [e,f] tend to differ ($P<0.09$).
[1] 100B: 100% biological piglets; 50B50A: 50% biological piglets and 50% adopted piglets; 100A: 100% adopted piglets.
[2] Taking into account the nutritive nursing episodes.

and $13.0 \pm 1.92\%$ at days 1, 2, 4 and 6, respectively) at TP1. At TP2 of day 1, the number of fights for teats was lower ($P<0.05$) in 100B treatment than in 50B50A and 100A treatments and the percentage of piglets involved in these fights tended to be lower ($P<0.07$) in 100B compared to 100A treatment (Table 2). The number of fights for teats tended to be lower ($P<0.09$) in 100B than in 50B50A treatment, at TP2 of day 2 (Table 2). When all the biological piglets (100B, 50B) were compared to adopted piglets (100A, 50A), a lower number of fights ($P<0.05$) at TP2 of day 1 was observed in biological than in adopted piglets (1.59 ± 0.13 vs. 1.20 ± 0.12). On day 1 of TP2 piglets did not fight elsewhere in the cage. For the other three days of observation, the number of fights elsewhere in the cage (overall medians of 0.0, 0.02 and 0.04 for days 2, 4 and 6, respectively) and percentage of piglets involved in these fights (overall medians of 0.0%, 4.6% and 9.1% for days 2, 4 and 6, respectively) did not differ ($P>0.05$) among the treatments.

There were no differences ($P>0.05$) in percentages of piglets vocalising at TP1 (overall medians of 4.5%, 2.3%, 0.0% and 2.3% at days 1, 2, 4 and 6, respectively) or at TP2 (overall medians of 3.0%, 2.3%, 0.0% and 0.0% at days 1, 2, 4 and 6, respectively). The number of playful behaviour instances (overall medians of 0.0, 0.07, 0.36 and 0.45 at days 1, 2, 4 and 6, respectively) and percentage of piglets involved in playful behaviour (overall medians of 0.0%, 9.1%, 34.1% and 40.0% at days 1, 2, 4 and 6, respectively), at TP2, were similar ($P>0.05$) among treatments.

Weight of piglets on the cross-fostering day was not different ($P>0.05$) among treatments (1452 ± 24 g, 1462 ± 25 g and 1452 ± 13 g for 100A, 100B and 50B50A treatments, respectively). There was no effect of interaction between treatments and time periods of weighing ($P>0.05$) on weight of piglets during the nursing period. Differences in piglet weight were observed among all the time periods of weighing but no differences were observed among treatments (Table 3). Compared separately, 50B and 50A piglets that suckled the same dam showed similar ($P>0.05$) weight at weaning (5174 vs. 5058 g). Also, when all biological piglets (100B, 50B) were grouped, there was no difference ($P>0.05$) in weaning weight (5137 g vs. 4987 g) compared to adopted piglets (100A, 50A). Overall survival rate was $97.2 \pm 0.76\%$ without difference ($P>0.05$) among treatments.

4. Discussion

Sows recognise their own piglets by olfactory cues (Algers and Uvnäs-Moberg, 2007), and may accept, reject or even kill alien piglets. Although sows can accept alien offspring quite well (Dellmeier and Friend, 1991), they are more aggressive toward fostered piglets than their own offspring when cross-fostering is performed all through the lactation (Horrell and Bennett, 1981; Price et al., 1994), except for the first day after farrowing (Robert and Martineau, 2001). Indeed, more females can be aggressive toward fostered piglets if they are two or more

Table 3
Weight (g) of biological and cross-fostered piglets (LSmeans ± SEM).

Weight (g)	100A[1]	100B[1]	50B50A[1]	Mean
Number of litters	13	13	13	
Day 4	1971 ± 34	2016 ± 34	1961 ± 34	1983 ± 20a
Day 7	2597 ± 56	2700 ± 56	2653 ± 56	2650 ± 33b
Day 10	3341 ± 80	3483 ± 80	3409 ± 80	3411 ± 46c
Day 13	4090 ± 99	4285 ± 99	4245 ± 99	4207 ± 57d
Day 16	4900 ± 115	5113 ± 115	5129 ± 115	5047 ± 66e
Mean	3380 ± 74	3519 ± 74	3479 ± 74	

There were no significant differences ($P > 0.10$) among treatments.
Different letters in the column indicate differences among days ($P < 0.05$).
[1] 100B: 100% biological piglets; 50B50A: 50% biological piglets and 50% adopted piglets; 100A: 100% adopted piglets.

days older compared to piglets cross-fostered within 2–9 h (66.7% vs. 16.7%) after farrowing (Price et al., 1994). In the present study, the aggressiveness of females toward the piglets involved only 5.1% of females and 1.6% (7/429) of piglets, and none of them were injured. This low aggressiveness is probably explained by cross-fostering being performed on average at 20 h after farrowing, which is consistent with results of previous studies (Dellmeier and Friend, 1991; Robert and Martineau, 2001) in which piglets were cross-fostered until 48 h after farrowing. Furthermore, the small number of dam attacks can also be explained by the fact that older females, as those used in this study, may be more experienced and adapt more easily to adopted piglets. According to Broom (1983), previous experience of the sow contributes to the reduction of attacks to piglets.

Similar number of nutritive nursing episodes among the treatments demonstrates that mothers can quickly adapt to a new litter as long as cross-fostering occurs early after birth. It has been shown, through direct visual observation for two hours after cross-fostering or by video recording during the first 15 h following adoption, that the number of nutritive nursings is not influenced by the fact that suckling piglets are biological or adopted unless piglets are cross-fostered throughout lactation (Robert and Martineau, 2001).

The absence of difference in the percentage of missed nursing episodes among adopted and biological litters is in agreement with results of Price et al. (1994) who performed cross-fostering until 48 h after farrowing. This result is probably due to the fact that most piglets have not yet defined their teat order at the time of cross-fostering, which results in less fighting and, consequently, in less failed nursing episodes. In the study of Deen and Bilkei (2004), litter type and litter size affected the percentage of missed nursing episodes. Low-birthweight piglets (0.9–1.0 kg) missed more nursing episodes when raised in large (12 piglets) than in small litters (8 piglets) together with average-birthweight (1.2–1.6 kg) or high-birthweight (> 1.6 kg) piglets. A stable teat order among piglets in a litter is developed within the first week after birth (de Passillé et al., 1988a, 1988b; Orihuela and Solano, 1995) to ensure that all piglets have access to a functional teat, avoiding fighting for teats and the occurrence of missed nursing episodes (de Passillé et al., 1988a; de Passillé and Rushen, 1989).

Despite the fact that behaviour immediately after cross-fostering did not differ among 50B and 50A piglets, foster piglets are expected to find their new environment strange. Generally, fostered piglets spend a long time wandering around the cage and vocalising in the first two to six hours after being mixed and huddled together, apart from the residents and consequently they lose some nursing episodes (Horrell and Bennett, 1981; Neal and Irvin, 1991; Robert and Martineau, 2001; Straw et al., 1998). Indeed, there were more missed nursing episodes in 50A than in 50B piglets on the cross-fostering day, although their performance up to weaning was not affected. Horrell and Bennett (1981) observed slower growth when multiple piglets had preference for the same teat. However, McBride (1963) noted that a loss of a preferred teat at a few hours of age is not as serious as a loss of a preferred teat at about twenty-four hours of age.

The fact that adopted piglets did not vocalise more than biological ones, both before and after milk letdown, is probably related to the fact of being transferred within 24 h after farrowing. Although piglets have the ability to identify their mother's odours as early as 12 h of life (Morrow-Tesch and McGlone, 1990), no increase in vocalisation was also observed when cross-fostering occurred within 26 h after farrowing (Price et al., 1994; Robert and Martineau, 2001).

Biological and adopted piglets showed a similar engagement in fights before milk letdown corroborating with the observation that the number of fights for teats before milk letdown is not affected in litters cross-fostered on average at 26 h after farrowing (Robert and Martineau, 2001). On the other hand, more fights were observed among fostered piglets compared to control piglets when cross-fostering was carried out after they were two days old (Horrell, 1982). The fact that cross-fostering was performed before piglets had defined their teat order and the fact that the number of piglets was less than the number of teats, could explain the lack of increase in fights for teats in the current study. According to Deen and Bilkei (2004), the size of the litter affects the time spent in fights for teats. Low-birthweight piglets (0.9–1.0 kg) suckling in large litters (12 piglets) spent more time in fights for teats than high-birthweight (> 1.6 kg) and average-birthweight (1.2–1.59 kg) piglets.

After milk letdown, piglets resume massaging at udder for 15 min until no extra milk can be withdrawn

(Ellendorff et al., 1982). This massage may be associated with stimulation for future milk production (Algers and Jensen, 1985, 1991) and to serve to scent-mark specific teats, improving teat order establishment (McBride, 1963). No difference in the number of fights for teats after milk letdown among fostered and control litters is reported by Robert and Martineau (2001), but occurrence of fights was evaluated only at one successful nursing period 24 h after cross-fostering. In the present study, four consecutive nursings were evaluated and fewer fights for teats were observed in biological piglets only after milk letdown on the first day of evaluation. Biological piglets are likely already familiar with the environment, their dam and their littermates, in contrast to the adopted piglets of which at least 50% of piglets were not familiar with one another. Because most piglets had probably not yet defined their specific teat, they had to rub and massage the teat they had chosen, as a marker signal. Piglets usually rub different teats before they decide their specific teat and if they find a teat already taken by any other piglet, fights for it can occur (Hartsock and Graves, 1976). However, the lower teat fidelity of piglets sucking at unfamiliar sows (Puppe and Tuchscherer, 1995) perhaps explains the similar engagement in fights of adopted and biological piglets before milk letdown, and from the second day of life onwards after milk letdown.

The results concerning the effect of cross-fostering on growth performance are controversial. The similar weight of biological and adopted piglets of this study is in agreement with results of some studies (Bishop, 2011; Milligan et al., 2001; Neal and Irvin, 1991), in which piglets were cross-fostered until 48 h after farrowing. Nevertheless, even with cross-fostering occurring within 24 h (Fix et al., 2010) or 36 h of birth (Stewart and Diekman, 1989) cross-fostered piglets were lighter at weaning than those nursed by their biological dams. Piglets that frequently engage in fights at suckling miss more nursings and gain less weight compared to piglets that fight seldom (de Passillé et al., 1988a). The number of fights for teats and the percentage of missed nursing episodes were not different among the treatments, which may explain their similar performance during lactation.

The similar survival rate of biological and adopted litters is in agreement with Stewart and Diekman (1989) who did not observe any difference in mortality between fostered piglets and piglets raised on their own dam. However, other authors have reported a tendency for increasing pre-weaning survival (Bishop, 2011) or an increase between 10% and 40% in pre-weaning survival rate in cross-fostered litters (Arango et al., 2006; Cecchinato et al., 2007; Marcatti Neto, 1986). The very low mortality rate observed (on average 2.8%) in the current study might be explained by both the high birth vigour score and birth weight of piglets (on average 1455 g). Birth weight has been associated negatively with mortality rate (Hartsock and Graves, 1976) and survival rate did not increase in adopted piglets when the birth score was similar among cross-fostered and biological litters (Neal and Irvin, 1991). It is also possible that the high parity sow composition (5th parity) used in this study contributed to the low mortality of piglets.

5. Conclusions

Cross-fostering performed soon after birth (within 24 h) does not adversely affect the behaviour of piglets until milk letdown. Biological piglets fight less after milk letdown, but survival rate and growth performance are not reduced in adopted piglets. Cross-fostered litters can be composed of only adopted piglets since no prejudice on behaviour during nursing, growth performance and survival rate was observed in litters composed exclusively of adopted piglets.

Conflict of interest statement

We are sending the "conflict of interest statement" regarding the manuscript "effects of cross-fostering within 24 h after birth on pre-weaning behaviour, growth performance and survival rate of biological and adopted piglets". We would like to inform that the authors have no conflict of interest to declare.

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